Measurement of the effect of digital play therapy using biological information

Hoshina, Atsushi; Horie, Ryota; Giannopulu, Irini; Sugaya, Midori

Published in:
Procedia Computer Science

DOI:
10.1016/j.procs.2017.08.104

Published: 01/01/2017

Document Version:
Publisher's PDF, also known as Version of record

Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 112 (2017) 1570–1579

Procedia Computer Science

www.elsevier.com/locate/procedia

International Conference on Knowledge Based and Intelligent Information and Engineering Systems, KES2017, 6-8 September 2017, Marseille, France

Measurement of the Effect of Digital Play Therapy Using Biological Information

Atsushi Hoshina[a], Ryota Horie[a], Irini Giannopulu[b], Midori Sugaya[a] *

[a]*Shibaura Institute of Technology, Tokyo, Japan*
[b]*Bond University, Gold Coast, Australia*

Abstract

We developed the new therapy device named "Digital Play Therapy Device", which combines house-shaped device with sensors attached and CG. The device was targeted for children with learning disabilities. We obtained the result from routine developed children, and obtained the result of increasing the number of speaking and decreasing the number of miscommunication, comparing to normal dollhouse. However, it's difficult to compare these results objectively. This paper analyzes the effect of "Digital Play Therapy Device (DPTD)" with more detailed method by using biological information. We compared the effect between DPTD and just operating house-shaped device, DPTD and just operating CG. Analysis of the experiment indicates that participants who experienced DPTD exerts higher concentration than operating house-shaped device or CG individually.

Peer-review under responsibility of KES International

Keywords: Therapy, Biological Information, Concentration

1. Introduction

The Digital Dollhouse we proposed enhanced traditional psychological play therapy with digital sensors and computer graphics combined together [1]. For the children, the environment is much like their home, so it is

* Midori Sugaya. Tel.: +81-03-5859-8517.
E-mail address: doly@shibaura-it.ac.jp

1877-0509
Peer-review under responsibility of KES International
10.1016/j.procs.2017.08.104

possible for them to immerse themselves through playing with the device. We consider that this environment is adequate for training the children to improve the required social skills. To accelerate the basic effect of the dollhouse and compensate to meet the requirements, various sensors are installed to sense their physical world, to share feelings and emotion with one another; the result would be visualized on the computer screening in order to share information more easily. Though they share the sense of the physical world in the dollhouse and the visual appeal of augmented reality on the computer, we assumed that children would easily immerse themselves in play and express themselves by sharing the situations visually and sensuously with the trainee. Based on it, we evaluated with a 6-year old child that is neurotypical, who is the almost same developmental level of the developmental disorder children with higher age. It obtains significant difference in reaction of children that compared with normal dollhouse especially in taking the responsive actions are twice as much as the normal device, and for the abstract concept three times, the number of miscommunications are 80% less than the normal one. Even more, children spent playing with this device twice as longer time as the normal device. Based on the result, we, brain scientist and human computer interaction researchers, have an assumption that there is a possibility for enhancing biological effect on collaboration of touching and viewing, compared with just touching, and just viewing. Based on this assumption, we define the cooperation of the action of touching the device, and reflection of action to CG for viewing the result as a feedback of their action, and proposed Digital Play Therapy Device. Fig. 1 is image of our proposed device. It includes not only the collaboration method of house-shaped device and CG, but also present the novel human-computer interaction technology that collects touching information of humans with several sensors and present it for some representative image for the display.

Fig. 1. Digital Play Therapy Device

In this paper, a first step of our research, we will present an experimental evaluation that uses biological responses of participants with brainwave and heartbeat. In the field of using biological information for estimating human consciousness, many researchers had proposed various methods using Galvanic Skin Reflex (GSR), Electrocardiogram (ECG), breathing rate and Electro Encephalogram (EEG). Some researchers proposed a method of estimating “Wakuwaku (Japanese word mainly represents excitement)” by using heart rate, earned from ECG and GSR [4]. The field of measuring brainwave using EEG, some researchers showed the result of measuring concentration and relaxation when playing with toys [5].

In this paper, we used heartbeat and brainwave for evaluating DPTD. Heartbeat was treated as the measurement of excitement and stress, and brainwave were treated as the measurement of concentration and relaxation. The result of the experiment showed that DPTD has various results, different from each participant. Especially, concentration showed significant difference.

This paper’s sections are organized as follows. In Section 2, we present the Digital Play Therapy Device, and the evaluation method of the device. In Section 3, we describe implementation of DPTD with new functions implemented. In Section 4, we analyzed and evaluated the result of the experiment which used DPTD. We concluded the paper in Section 5.

2. Digital Play Therapy Device

2.1. Issues

The therapy device named "Orange Roof House", which we proposed previously, showed effect of enhancing the child's number of speaking and conation of playing. From the result, the is a suggestion that the device might be efficient for operating as a therapy device which enhances children's communication ability [1]. However, the result earned from the experiment we conducted on previous work were not clear that the effect was influenced by the specificity of the device or the existence of the therapist, and revealing this influence were one of the remaining subjects. It is suggested that the specificity of the device is the method of touching concrete object which can be touched intuitively, and syncs the information obtained from sensor attached inside the device to CG. We named the device as "Digital Play Therapy Device (DPTD)".

2.2. Evaluation of Using Biological Information

To deal with the issues we noticed, comparison and verification of the combination of house-shaped device and CG is required. Accordingly, we suggest to compare DPTD, and house-shaped device or CG operated individually. And then, we compared the effect of these three devices to reject the effect of therapy. To evaluate, we suggest to use biological information. The main reason for using biological information is that it can record unconscious reaction of human. Unlike the subjective evaluation such as using questionnaire, it is conceivable that evaluation of biological information is more objective. It is essential to make the difference between the effect of DPTD, house-shaped device and CG to recognize the superiority of our proposal. There are various types of biological information, and this paper uses heartbeat and brainwave for evaluation.

2.3. Evaluation of Using Biological Information

In heartbeat, we suggest to use heartrate, which is defined as the number of time heart beats in one minute (Beats Per Minute; BPM), and LF/HF, which is a ratio of autonomic neuron, especially sympathetic nerve (LF) and parasympathetic nerve (HF). Heartbeat sensor used to measure heartbeat is a type attached on the chest. Heartbeat is used to measure emotions, especially positive emotions such as relaxation [6] and negative emotions such as stress [7]. Moreover, some researchers suggest to use heartbeat to measure "Wakuwaku", which is a Japanese word mainly used to express excitement [4]. LF/HF is widely used for a measurement of stress [7]. It is known that sympathetic nerve (LF) vitalize when the stress increases and parasympathetic nerve (HF) vitalize when the stress decreases.

In brainwave, we suggest to evaluate concentration and relaxation by using alpha, beta, gamma and delta wave. In this research, "MindWave Mobile" furnished by "NeuroSky" [8] is used to measure brainwave. This brainwave sensor can measure Attention and Meditation, which are calculated by its own algorithm using brainwave obtained. These are values in the range of 0 to 100. Attention is a value used to measure concentration. Higher the value is, more concentration does the person with the sensor attached exerts [9]. Meditation is a value used to measure relaxation. Higher the value is, more relaxed does the person with the sensor attached exerts [5].

3. Design and Implementation of DPTD

3.1. Summary of the device

To measure the effect of DPTD, we designed and implemented the device with house-shaped device with sensors and switches attached, and PC displaying CG which mimics the scenery of house-shaped device, combined together (Fig. 2).

Fig. 2. Digital Play Therapy Device (DPTD) with new implementation

The left side of Fig. 2 is a house-shaped device, which is structured as a hardware of the device. The house-shaped device controls rabbit-shaped doll and controller with switches and dial as an input of the device. The right side of Fig. 2, PC displaying CG is a software designed and implemented for DPTD. The difference between CG indicated in section 2.1 is the function of displaying rabbit-type character, which is capable of changing its emotion. With these new functions implemented, we enhanced traditional DPTD which emphasizes the approach of cognition and the operation feeling.

3.2. Hardware Implementation

The device uses Arduino [10] for operating multiple sensors. The device operates three types of sensors and LED. Sensors used in the device and the function implemented is listed on Table 1.

Table 1. Type of sensor used and function implemented

Sensor	Function
Pressure sensor	Recognition of the character
Tact switch	Controlling air conditioner and light's main power, adjusting temperature
Variable resistance	Adjusting brightness of CG and LED

The device is structured with 3 pressure sensors, a variable resistance and 4 tact switches. Next, circuit is designed to embody functions listed on Table 1. Circuit diagram, design of connecting Arduino and sensors is listed on Fig. 3.

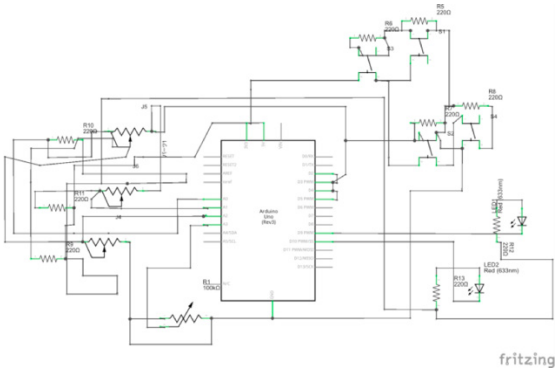

Fig. 3. Circuit diagram of DPTD

3.3. Software Implementation

In order to output the sensor information obtained via microcomputer in real time on CG, support of the middleware is necessary. In this research, we used StandardFirmata [18] as a firmware for Arduino, so that input information from sensors attached on Arduino can be obtained from program configuring CG. Software and hardware stack are listed on Fig. 4.

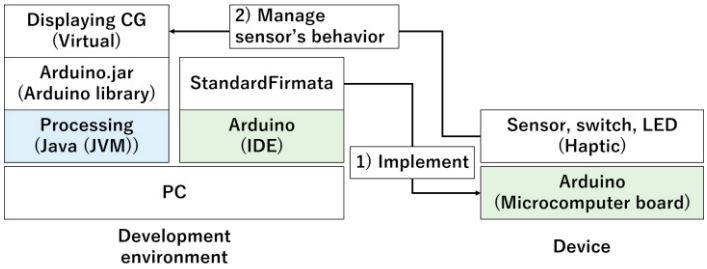

Fig. 4. Development environment

DPTD is a device which is assumed to be operated by two persons, the operator and the explainer. The operator experiences therapy by operating sensors attached to the house-shaped device. In addition, the explainer can change the season and time virtually displayed on CG by operating the keyboard. This process may encourage the operator to act to manipulating the emotions of the characters that appeared on CG. There are four types of emotions implemented, which are shown in Fig. 5.

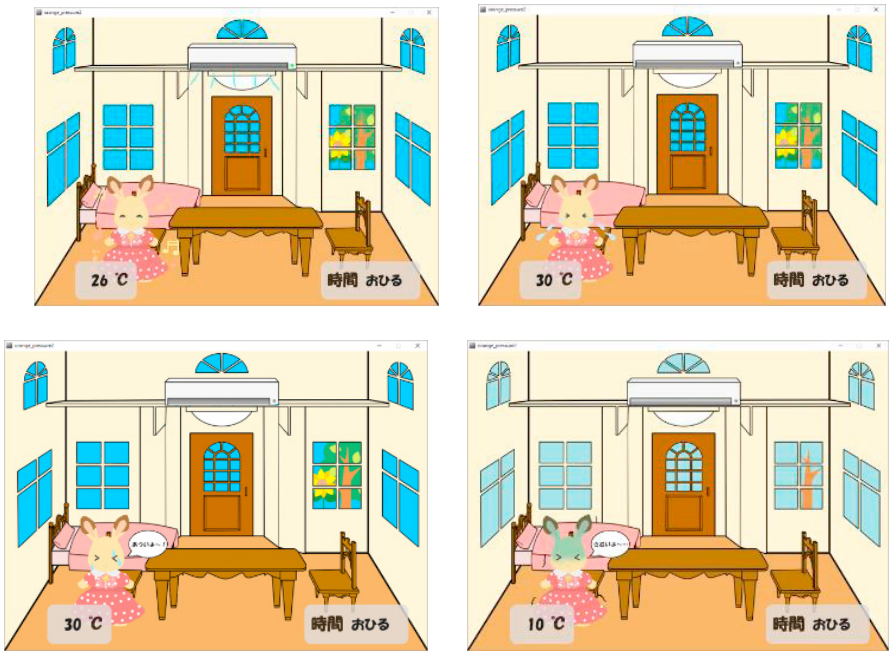

Fig. 5. Character expressing its emotion

Manipulation of the character is managed by three pressure sensors implemented in the house-shaped device. Position of the character displayed on CG changes depending on where the doll was placed. Changes in the emotion of the character indicated on Fig. 5 are performed by explainer operating the keyboard. The emotion of pleasure

used when the operator performed the operation assumed by the explainer (upper left of Fig. 5), the sad feeling used when the operator failed on performing the operation assumed (upper right of Fig. 5), the emotion complaining of the heat (bottom left of Fig. 5), and the emotion complaining of the cold (bottom right of Fig. 5). By using these emotional expressions, it is possible for the explainer to explain the situation or feedback of the operator's actions more clearly than to explaining it verbally.

3.4. Operation of House-shaped device only and CG only

In this study, in comparing the effects of DPTD, we considered that it is necessary to compare the effects when the house-shaped device or CG is operated individually. For this reason, these devices were individually implemented by changing the operation, apart from DPTD.

The difference between the operation of a house-shaped device only and DPTD is the existence of CG output. Therefore, change of the situation is verbally explained by the explainer. The difference between operation of CG only and DPTD is the existence of operation of a house-shaped device. For CG alone, operator operates the device by using the keyboard.

4. Experiment and Evaluation

4.1. Abstract of the experiment

The purpose of the experiment is to compare the effect of DPTD, house-shaped device and CG by using biological information. There were 28 participants (male: 24, female: 4), and these participants were divided into four groups, 7 participants per group. Order of experiencing device is different from each group, and the difference between these groups were compared. Group number and the device experiencing order is listed on Table 2.

Table 2. Device experiencing order

Group number	Device experiencing order
Group 1	House-shaped device, CG, DPTD
Group 2	CG, House-shaped device, DPTD
Group 3	DPTD, House-shaped device, CG
Group 4	DPTD, CG, House-shaped device

4.2. Procedure of the experiment

The experiment was conducted in quiet room with only participant and explainer. This environment was structured to minimize the influence to biological information. Experiment was progressed as the procedure listed on Fig. 6.

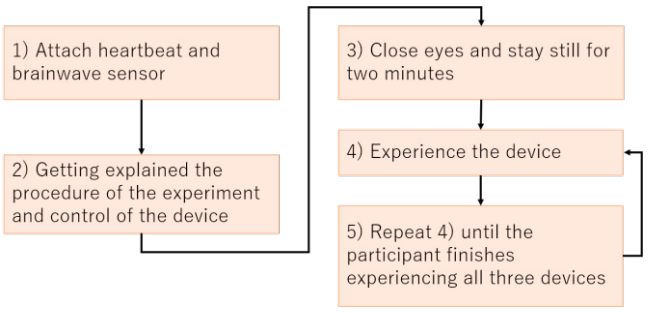

Fig. 6. Procedure of the experiment

First of all, participant attached the heart rate sensor and the brainwave sensor ((1) in Fig. 6). After that, participant was explained the procedure of the experiment from explainer, and received the explanation about the operation method of DPTD, house-shaped device and CG from the explainer ((2) in Fig. 6). After receiving the explanation, measurement of biological information is started, and the participant is seated and stayed still with their eyes closed for 2 minutes ((3) in Fig. 6). The biological information measured in this procedure was used to calculate changing rate of biological information, to be explained in Section 5.2. After procedure (2), the participant experienced the device, then took a break between each device ((4), (5) in Fig. 6) according to the order of device experiences of the group to which it belongs (group description on Table 2)).

4.3. Method of Analysis

Biological information during the experiment was obtained by heartbeat and brainwave sensor. Next, changing rate of biological information obtained is calculated by the formula listed below.

$$Changing\ Rate\ (\%) = \frac{\left((Average\ of\ biological\ information\ while\ operating\ the\ device) - (Average\ of\ biological\ information\ while\ stilled)\right) * 100}{(Average\ of\ biological\ information\ while\ stilled)} \quad (1)$$

This formula is used to calculate the percentage of biological information changed when operating the device, comparing to biological information while staying still [14]. In this paper, analysis of biological information was done by using the changing rate.

After calculating the changing rate, all the group's biological information obtained from each device is analyzed with two-way factorial ANOVA without replication. Article with significant difference is additionally analyzed with t-test, which compares the average of DPTD and Haptic, DPTD and Virtual.

4.4. Analysis of the brainwave sensor

In this research, Attention and Meditation, value obtained from brainwave sensor "MindWave Mobile" is used for evaluation of brainwave. This is a value calculated by its own algorithm, and used in several researches [4][8]. However, it's difficult to recognize the meaning of the value, since the value is furnished in the range of 0 to 100, and the calculation of the value uses traditional brainwaves. The problem is that the algorithm is not disclosed. For detailed evaluation and discussion, clarification of the relation between Attention, Meditation and traditional brainwaves is required.

To reveal this relation, correlation analysis which derives Pearson product-moment correlation coefficient values is used. Value is in the range of -1 to 1, which shows positive correlation when the value is close to 1, and negative correlation when the value is close to -1. Analysis were done by using brainwave data obtained from 28 participants who participated in the experiment. Average of all 28-correlation coefficient between Attention and brainwaves, Meditation and brainwaves were calculated. The result is graphed, and it's listed on Fig. 7.

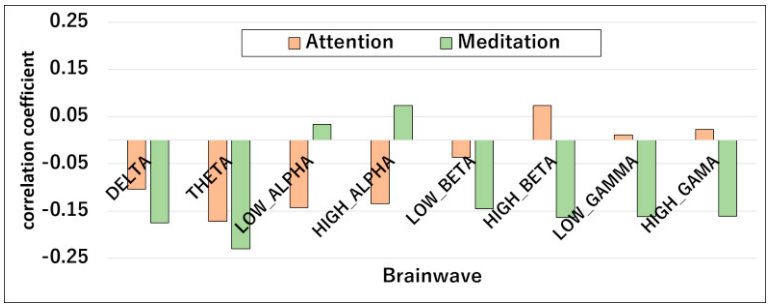

Fig. 7. Experiment scenery when experiencing DPTD

Result from Fig. 7 shows that the correlation of delta wave, theta wave and low beta wave shoed negative correlation between Attention and Meditation. Evaluation followed analyses Attention, Meditation and each

brainwave's frequency band. To analyse the correlation, consciousness which can be recorded from the brainwave needs to be revealed. In Table 3, brainwave's frequency band used for analysis and the consciousness recorded from the bandwidth, and the result of correlation analysis is listed.

Table 3. Type of brainwave used for analysis and consciousness measured from that brainwave

Type of brainwave	Consciousness measured	Correlation of Attention	Correlation of Meditation
alpha wave	Relaxation	Negative	Positive
High beta wave	Concentration	Positive	Negative
gamma wave	Concentration	Positive	Negative

Discussion of result of the analysis listed on Table 3 is written below.

1) Attention

The correlation of Attention and alpha wave recorded negative correlation. This means that higher the value of Attention is, lower level of relaxation the participant shows. Correlation of Attention and high beta, low gamma and high gamma recorded positive correlation. This means that higher the value of Attention is, higher level of concentration the participant shows.

2) Meditation

The correlation of Meditation and alpha wave recorded positive correlation. This means that higher the value of Meditation is, higher level of relaxation the participant shows. Correlation of Meditation and high beta, low gamma and high gamma recorded negative correlation. This means that higher the value of Meditation is, lower level of concentration the participant shows.

The following analysis of Attention and Meditation is referred as the analysis result written above.

4.5. Result of the experiment

Graph listed the variance of biological and P-value, which is calculated by the result of ANOVA is listed on Fig. 8.

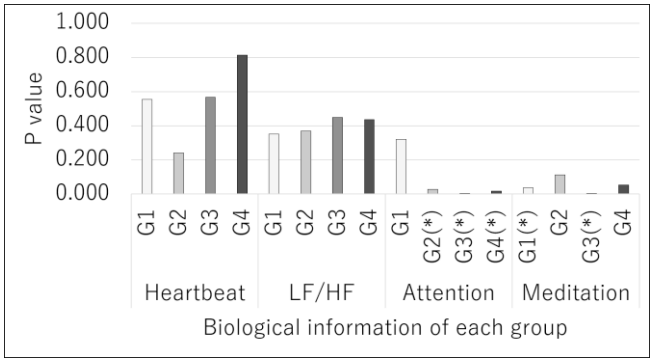

Fig. 8. P-value of biological information each group recorded (*: $p<0.05$)

Result from Fig. 8 indicates that biological information with P-value recorded lower than 0.05 was group 2, 3 and 4's Attention and group 1, 3's Meditation. To confirm the significant difference between DPTD and other devices, data was analysed by t-test with pared two samples for means. P-value calculated by t-test is listed on Table 4. Furthermore, transition of biological information's changing rate, which biological information with significant difference appeared by either comparing DPTD and Haptic, DPTD and Virtual are listed on Fig. 9.

Table 4. Biological information and t-value (*: t<0.05)

Group number	Biological information	p-value calculated between house-shaped device and DPTD	p-value calculated between CG and DPTD
1	Meditation	0.092	0.611
2	Attention	0.966	0.078
3	Attention	0.005*	0.138
	Meditation	0.032*	0.014*
4	Attention	0.034*	0.054

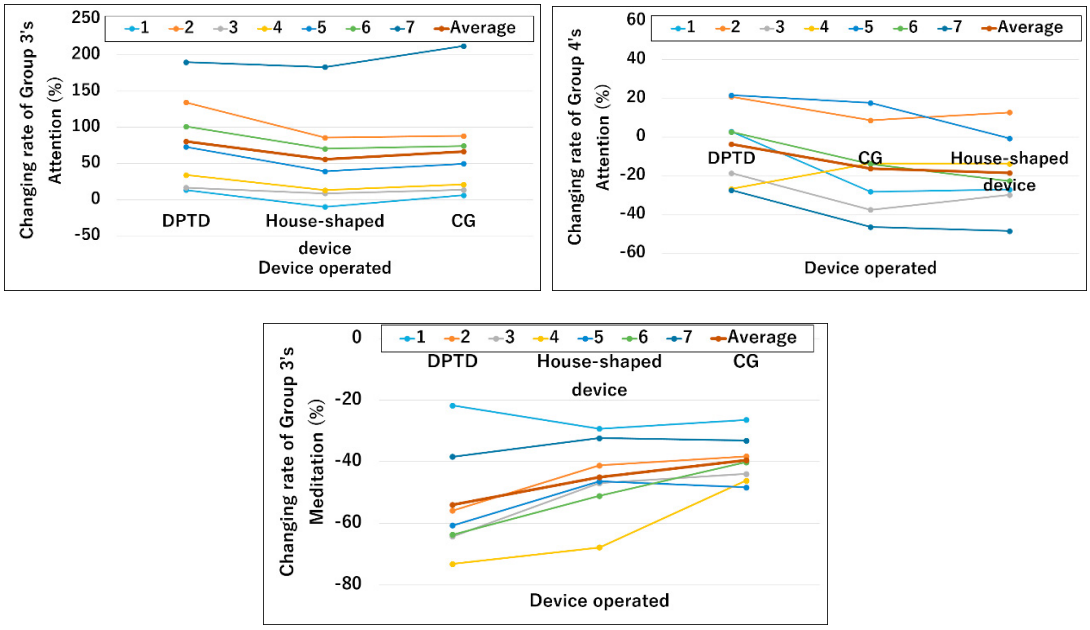

Fig. 9. Transition of biological information (Upper left: Group 3's Attention, Upper right: Group 4's Attention, Bottom: Group 3's Meditation)

Result listed on Table 4 indicates that Group3 and 4, which is the group operated DPTD earlier than house-shaped device and CG, showed significant difference in the result of t-test. Discussions of Attention and Meditation recorded from Group 3 and 4 are listed below.

1) Attention

The result of t-test showed significant difference on group3 and 4, and it were only found in the t-value between house-shaped device and DPTD. Results indicated in upper left and right of Fig. 9 shows that all participants except for group4's participant 4 recorded higher Attention in DPTD. However, there were no significant difference found in the t-value between CG and DPTD. From the analysis of section 4.4, the ascent of Attention and the level of concentration are connected together. From this knowledge, it can be analysed that the control of CG enhances concentration. Moreover, combination of house-shaped device and CG enhances higher level of concentration than just operating device with Haptic only.

2) Meditation

The result of t-test showed significant difference only on group3, but the group showed significant difference on both the t-value between house-shaped device and DPTD, CG and DPTD. Result indicated in the bottom of Fig. 9

shows that all participants except for participant 1 recorded the lowest Meditation in DPTD. The analysis result on section 4.4 indicates that higher the Meditation is, higher the relaxation and lower the concentration is. From this knowledge, it can be analysed that DPTD doesn't enhances relaxation comparing to other 2 devices, but enhances concentration.

4.6. Summary

Results of the experiment indicates that DPTD showed significant difference on brainwave. Especially, it showed significant difference when experiencing the device of DPTD earlier than experiencing the device of house-shaped device or CG. Tendency of brainwave transition of DPTD is that it showed high concentration. We suggest that combining CG information to house-shaped device might enhances concentration level. In the future work, we're planning to enhance the function of DPTD.

5. Conclusion

This paper conducted the research about the effect causing "Orange Roof House", device which combines house-shaped device and CG, from enhancing children from speaking and persisting time playing with device. We proposed the method of combining device and CG as "Digital Play Therapy Device", and proposed the evaluation method of using biological information. Biological information is widely used to measure the level of human consciousness such as concentration and relaxation, and found out to be suitable for quantitative and objective evaluation. Information of heartbeat and brainwave sensor was used for evaluation. And, the device of DPTD was designed and implemented for evaluation. Furthermore, device of house-shaped device and CG operating individually was also implemented. In the experiment, DPTD showed significant difference on exerting higher level of concentration.

References

1. Midori Sugaya, Yoshiko Okada, Hirotaka Osawa, Irini Giannopulu. 2015. Feel as Agent: Immersive Dollhouse Enhances Sociality of Children with Developmental Disorders. Proceedings of the 3rd international conference on Human-Agent Interaction (HAI).
2. Hiroshi Ishii and Brygg Ullmer. 1997. Tangible Bits: Towards Seamless Interfacesbetween People, Bits and Atoms. CHI 97, 22-27 March, 234-241
3. Wouter M. Bergmann Tiest. 2010. Tactual perception of material properties. Vision Res, 50(24), 2775-2782.
4. Michiko OHKURA，Masahide HAMANO，Hiroyuki WATANABA. 2010. MEASUREMENT OF "WAKUWAKU" FEELING GENERATED BY INTERACTIVE SYSTEMS USING BIOLOGICAL SIGNALS．KEER．
5. Katie Crowley，Aidan Sliney, Ian Pitt，Dave Murphy．2010. Evaluating a Brain-Computer Interface to Categorise Human Emotional Response．IEEE, 276-278.
6. Yumi Shibagaki, Kozue Ogawa, Hiroshi Hagiwara. 2010. Evaluation of Physiological Indices to Indicate Sleepy or Relaxed States Using Illuminance Stimulation. T. SICE, Vol.46, No.1, 65-71
7. Nis Hjortskov, Dag Risse´n, Anne Katrine Blangsted, Nils Fallentin, Ulf Lundberg, Karen Søgaard. 2004. The effect of mental stress on heart rate variability and blood pressure during computer work. European Journal of Applied Physiology, June 2004, Volume 92, Issue 1, 84-89
8. Mindwave, Retrieved May 9, 2016 from http://store.neurosky.com/pages/mindwave
9. Greeta U Navalyal，Rahul D Gavas．2014. A dynamic attention assessment and enhancement tool using computer graphics．Human-centric Computing and Information Sciences, 4:11
10. Arduino – Home. Retrieved May 9, 2016 from https://www.arduino.cc/
11. Processing.org. Retrieved May 9, 2016 from https://processing.org/
12. Arduino – Software. Retrieved May 9, 2016 from https://www.arduino.cc/en/Main/Software
13. Arduino – Firmata. Retrieved May 9, 2016 from https://www.arduino.cc/en/Reference/Firmata
14. Hiroaki Takatsu, Mitsuo Munakata, Osamu Ozeki, Kiyoko Yokoyama, Yosaku Watanabe, Kazuyuki Takata. 2000. An Evaluation of the Quantitative Relationship between the Subjective Stress Value and Heart Rate Variability. T.IEE Japan. Vol. 120-C, No.1, 104-110